Athanasius Kircher and the Progress of Medicine

When this subject was presented to me recently for critical consideration, I turned at once, for a summary of the matter, to GARRISON's indispensable *Introduction to the History of Medicine*. There, in the last edition (1929, 252), as in the first (1914), " the learned Jesuit priest, ATHANASIUS KIRCHER " appears with his portrait as " the earliest of the microscopists,... mathematician, physicist, optician, Orientalist, musician, and virtuoso, as well as a medical man... probably the first to use the microscope in investigating the causes of disease... found that the blood of plague patients was filled with a countless brood of ' worms,' not perceptible to the naked eye, but to be seen in all putrefying matter through the microscope... undoubtedly the first to state in explicit terms the doctrine of a *contagium animatum* as the cause of infectious disease."

In one of his *Essays on the Floating Matter of the Air in Relation to Putrefaction and Infection* (1881, 8), TYNDALL records KIRCHER's notion " that epidemic diseases may be due to germs which float in the atmosphere, enter the body and produce disturbance by the development within the body of parasitic life."

" In the writings of ATHANASIUS KIRCHER," says LOCY (1925, 201-2), " we have the first authenticated notices of microscopically minute living organisms... In 1658, in his *Scrutinium pestis*, KIRCHER gave a notable anticipation of the germ theory of disease... His conclusion had some observational basis and his idea that infection is due to living organisms was a remarkable anticipation which has received merited attention in recent times."

There is a brief paragraph about KIRCHER in NEWSHOLME's *Evolution of Preventive Medicine* (1927, 69), in which the last statement quoted from GARRISON is mentioned, and again in

LONG's *A History of Pathology* (1928, 95). ROBINSON, in *The Story of Medicine* (1931, 310), refers to KIRCHER as the " foremost German scholar of the age... the first to cast a suspicious eye upon recently revealed microörganisms, already regarding them as the cause of infectious diseases... In ascribing contagion to living organisms (*contagia animata*), he went beyond FRACASTORIUS."

MAJOR's *Classic Descriptions of Disease* (1932) gives space to a biographical note similar in tenor to GARRISON's, and to several passages translated from the German edition (1680) of the *Scrutinium pestis*. He believes that KIRCHER " may possibly have seen larger bacilli." More recently, WOLF's *A History of Science, Technology and Philosophy in the 16th and 17th Centuries* (1935, 425, 443) mentions " LEEUWENHOEK's and KIRCHER's bacteriological discoveries " and expresses the opinion that " FRACASTORO's views were greatly strengthened when ATHANASIUS KIRCHER, in 1671, published his account of the microscopic organisms which he said he observed in the blood of plague victims." GAY, *et al.*, in their *Agents of Disease and Host Resistance*, (1935, 123), refer to this observation.

Enough has been said to make it clear that KIRCHER occupies at the present time a recognized place in the history of medicine. Opinions as to the value of his contributions, however, vary between wide extremes. One of the foremost in the ranks of KIRCHER's admirers and partisans is J. J. WALSH. In *Catholic Churchmen in Science* (I, 1913, 113), he says: " KIRCHER, more than perhaps any other, can be said to be the founder of modern natural science." Farther on (133), he declares: " Undoubtedly the most interesting of Father KIRCHER's scientific books is his work on the Pest,... which... reached conclusions which anticipate much of what is most modern in our present-day medicine... it is one of the classics which represent a landmark in knowledge for all time. It merits a place beside such books as HARVEY on the Circulation of the Blood or even VESALIUS on Human Anatomy." " In this book," WALSH says in *The Popes and Science* (1912, 239) " he stated in very clear terms the modern doctrine of the origin of disease from little living things, which he called corpuscles. Because of this TYNDALL attributes to Father KIRCHER the first realization of the role that bacteria

play in disease. Even more wonderful than this, however, was Father KIRCHER's anticipation of modern ideas with regard to the conveyance of disease. He insisted that contagious diseases, as a rule, were not carried, as had been thought, by the air, but were conveyed from one person to another, either directly, or by the mediation of some living thing."

These passages may reasonably represent one extreme of opinion. Near the other stands CLIFFORD DOBELL, who, in his *Antony van Leeuwenhoek and his little animals* (1932, 365ff), characterizes KIRCHER as a " priest with no biological or medical training," a " voluminous and reckless writer," " the veriest dabbler in science." " To me the *Scrutinium Pestis* appears as a farrago of nonsensical speculation by a man possessed of neither scientific acumen nor medical instinct. KIRCHER had obviously no conception of a real experiment—in the Baconian and modern sense." " Microscopists and *contagium animatum* both existed before KIRCHER began to write."

So much for current references to KIRCHER and his writings. What are the facts? I am indebted to the Harvard University Library for SENG's translation of KIRCHER's autobiography; to the Huntington Library for the opportunity to consult the first edition of *Ars Magna Lucis et Umbrae*; to the Lane Medical Library for the 1659 Edition of the *Scrutinium pestis*; and especially to Professor C. A. KOFOID of the University of California, who placed at my disposal his exceptional collection of KIRCHER's works, numbering more than twenty-five volumes.

II

Let us begin with what KIRCHER says of himself in his Autobiography as translated into German by SENG (1901).

He was born May 2, 1602, near Fulda, Grand Duchy of Saxe-Weimar, in the village of Geisa, 1300 of whose 1500 inhabitants were Catholics. He was the last of nine children of very pious parents, and was named Athanasius because of his father's great admiration for the courage and steadfastness with which the Alexandrian bishop had opposed the errors of ARIUS. Piously his father studied the sciences, especially theology and mathematics, collecting a considerable library that was lost in the

turmoil of the Thirty Years' War. In this devout and bookish atmosphere, ATHANASIUS passed his early years. He was taught music and Latin in the local elementary school. At ten he was making great strides in geography. Later, at the Jesuit college at Fulda, he studied grammar, Latin, Greek, Hebrew. Here, as he quaintly says, science was united with piety, under a Jesuit teacher. He found his companions among those of similar talents and zeal for holiness, and as the latter grew, learned to scorn boyish things. And here he might have received the news that the great *De Revolutionibus orbium celestium* of COPERNICUS had at last been placed (1615) upon the list of forbidden books.

During his adolescence KIRCHER received three proofs of God's mercy, being saved from death in a mill race, from being trampled by horses in a parade, from losing his way in a forest. These impelled him toward the service of God; and finally, after inner communion with the Holy Spirit, he chose the Society of Jesus. His novitiate began in October, 1618, at Paderborn. He was then sixteen years old.

For the next ten years, he pursued his studies in philosophy, logic, natural sciences, Oriental languages, theology. He was made a priest in 1628. It was at Speier, during his three years of probation, that he first saw Egyptian hieroglyphics and made up his mind to find a key that should decipher them.

From Speier KIRCHER was called to the Jesuit University at Würzburg to teach mathematics, moral philosophy, Hebrew and Syrian. Though the duties of his professorship were onerous, he nevertheless found time to write his first work, the *Ars Magnesia*, on a subject of early and enduring interest to him. It was published in 1631 and was received, according to the autobiography, with great approbation by the learned.

It was at Würzburg that KIRCHER envisioned the approaching destruction of the town and the college as a military consequence of the invasion of GUSTAVE of Sweden. Not disposed to await the enemy, he besought his superior to pray for the doomed institution, then picked up his papers and fled. For a time he was at Avignon, busy with map making, mathematics and the study of hieroglyphics. This last occupation attracted the attention of the learned Senator, NICHOLAS PEIRESC, who encouraged him with books, and was instrumental, as KIRCHER believed, in having

him called, before long, to Rome. There, in 1634, a year after GALILEO had been forced into retirement, he took up his residence as Professor of Mathematics at the Collegio Romano, which was his headquarters until his death in 1680.

During his life in Rome, a protégé of the powerful Cardinal BARBERINI and the friend of three successive Popes, Pater KIRCHER worked with tireless industry. More than forty volumes came from his busy pen, beginning with the *Prodromus coptus sive aegyptiacus* in 1636. For the most part they do not concern us here. Many of them are bulky folios, handsomely illustrated, their publication made possible by the generosity of two Emperors, of nobles of the Empire, Popes and Cardinals. This support, quite apart from its intrinsic value, gave the worthy father a great personal satisfaction that he made no effort to conceal.

Of his many works, only a few are noticed in the Autobiography. The list does not include the *Scrutinium physico-medicum contagiosae luis quae dicitur pestis* (1658), the small volume on which his reputation as a " medical man " was chiefly based. It does include the *Mundus subterraneus* (1665), which grew out of visits KIRCHER made in 1638 to Stromboli, Etna, and the Straits of Messina as a result of serious earthquakes in Calabria. *Magnes sive de arte magnetica* (1641), *Ars magna lucis et umbrae* (1646), and *Musurgia universalis* (1650), are mentioned also—three large works written to discharge obligations which he believed to have been imposed upon him by his professorship in mathematics.

It is with especial interest, however, that he refers to his work with hieroglyphics. It was his conviction, according to a writer in *Biographie universelle ancienne et moderne* (1818), that these as yet undeciphered characters had been invented by Egyptian priests to conceal from the crowd their secret doctrines. And it was to penetrate these mysteries that he had agreed to edit the comprehensive Coptic-Arabic dictionary that PIETRO DELLA VALLE had brought to Rome, in the belief that the Coptic idiom would provide the essential clue. The dictionary itself was preceded by the *Prodromus* already mentioned, that began with a brief sketch of Coptic grammar and is said to have led CHAMPOLLION to say that, notwithstanding its numerous errors, learned Europe owed to the labors of KIRCHER its first knowledge of Coptic. When the completed *Lingua aegyptiaca restituta* (1643) finally

appeared, it became, according to one generally hostile critic in *Allgemeine Deutsche Biographie* (1882), indispensable to research in the Egyptian language; this in spite of KIRCHER's careless editing. Yet it did nothing for the deciphering of hieroglyphs. As KIRCHER's studies on the latter proceeded, he felt the opposition of various critics. With the publication of the *Obeliscus Pamphilius* (1650), he made an expensive answer to his detractors based on the obelisk INNOCENT X had set up in the Forum Agonale. It was while studying this monument that KIRCHER undertook to restore gaps in the inscriptions due to mutilation of the stone. This experience, he relates, led him to make other predictions. During excavations preparatory to laying the foundations of a new building in the city, a buried obelisk had been brought to light. When three sides of it had been bared, and their inscriptions made out with the help of his friend PETRUCCI, KIRCHER ventured to predict what would be found when the fourth side should be exposed. Upon further excavation, what he had supplied was found to correspond accurately with the inscription on the stone. This extraordinary feat was laid by some both to divine and demoniac aid, by others to KIRCHER's familiarity with the material, as a result of long study. The reader is led to believe that the last was, indeed, KIRCHER's own view.

III

GARRISON refers to KIRCHER as the earliest of the microscopists. His meaning is not altogether clear. Simple magnifying glasses were being used here and there by the curious before the close of the sixteenth century. The compound microscope itself had been invented before KIRCHER was born and had been developed by GALILEO and KEPLER while KIRCHER was still in elementary school. As early as 1610, GALILEO had spoken of the limbs and eyes of insects seen with his instruments, as related by WODDERBORN (SINGER, 1915). Between that time and 1630, the microscope played a familiar role at the seances of the Accademia dei Lincei, and was actually given its present name by one of the members of the Academy, JOHANNES FABER (1628). Various natural objects were explored with its aid. By 1628, the founder of the society,

Duke FEDERIGO CESI, had discovered the spores of ferns, and he and his associates, including FONTANA and STELLUTI, made detailed observations on bees, drawings of which, magnified five diameters, were published by STELLUTI in 1630. At the same time, in England, where magnifying glasses had long been known, WILLIAM HARVEY (1628) was demonstrating the pulsing hearts of wasps, hornets, flies and lice, and noting the passage of food through the intestines of the last, "*ope perspicilli ad res minimas discernendas.*" He makes no mention of the compound instrument. It appears, however, that one of the portraits of HARVEY, dated 1639, shows in its background a microscope like that which DESCARTES had designed in 1637, of a type that has not persisted. Whatever his style of magnifier, HARVEY appears never to have seen the capillaries. This was some years before MALPIGHI, in 1660, noted capillaries in the lung and mesentery of the frog.

By 1662, ROBERT HOOKE, as the Curator of the newly organized Royal Society, had begun his demonstrations of microscopical objects, later described and figured in his *Micrographia* (1665), among them cork, with its minute cavities for which he invented the term *cell*. HOOKE's microscope was compound, arranged for the examination of solid objects illuminated by light passing through a condenser system.

Without the developments in the field of optics that took place during the next century, the compound microscope lagged in popularity. During the first half of the seventeenth century, the "flea glass" (*vitrea pulicaria*) came into general use, much as magnifying glasses are used today by amateurs. It was typically a short tube about the size of the thumb, fitted with a lens at one end and a plane glass at the other for the object. Such an instrument came into KIRCHER's hands, after his arrival in Rome in 1634, as a gift from Cardinal GIOVANNI CARLO. It is figured in the *Ars magna lucis et umbrae*, ed. 1646, and also in the edition of 1671. In the latter there appears what KIRCHER called by an odd but favorite perversion of the term, a *microscopium parastaticum*, a sort of flea glass fitted with a revolving wheel carrying several objects that could be passed under it. The text (p. 727) describes lenses of several forms, and mentions combinations of them in tubes, some of them colored for observations

of the sun. No compound microscope, however, is figured. We are indebted, according to SINGER (1915), to posthumous publications by ZAHN (1685) and BUONANNI (1709) for figures of two compound instruments, the one a tube, with a lens at each end, which could be screwed up and down in a simple stand; the other a similar tube placed horizontally in a much more elaborate stand with perforated stage, substage condenser and artificial light, and a fine adjustment by rack and pinion. According to SINGER (1914, 267), not one of his microscopes is to be found at present in the Museo Kircheriano at Rome.

IV

If, then, KIRCHER was not the earliest of the seventeenth century microscopists, was he, perhaps, the first in importance? What did he see with his microscopes? What discoveries did he make? How does his work compare with that of his contemporaries, from CESI to LEEUWENHOEK?

First of all, it may be said that nowhere in his voluminous writings did KIRCHER register any figures or detailed descriptions of the objects which his glasses magnified. By 1646, according to a summary paragraph in the *Ars magna lucis et umbrae* (p. 834), he had seen fleas that looked like wingless locusts, and mites that suggested hairy bears. He assured his readers that all sorts of beasts of land and air and water were represented by similar counterparts in the microscopic world; and that hairs were hollow. But, " I omit here," he said, " the wonders to be seen in the incubating eggs of birds, in the verminous blood of those sick with fever, and numberless other facts not known or understood by a single physician." " You will see," he continued, " not only animals but certain plants produce animals according to their nature, which spring up out of their putrid humors as though from seeds, including all kinds of flies and caterpillars; also the smallest of animals with a vast number and variety of motions, colors and almost invisible parts."

What significance shall we attach to this jumble of casual allusions? Do they contain any discoveries? Fleas and itch mites, in 1646, were not longer novelties to microscopists. PEIRESC, a friend of KIRCHER, and a member of *dei Lincei*,

had written to a correspondent in 1622 of the *occhiale* by means of which fleas were magnified to the size of wingless locusts, and cheese mites to the size of flies (SINGER, 1915). MAYERNE in his preface to the first editon of MOUFFET's *Insectorum Theatrum* (1634), had described with much verisimilitude the " hand-worms " or itch mites so common in his day. HARVEY (1628) had already seen the hearts of various insects, including lice, with his *perspicillum*, at the same time that he was making observations on the embryo chick, presumably with the aid of his lens here also. What KIRCHER says about the derivation of animals from plants, THEOPHRASTUS and PLINY had already suggested to him, the latter referring also to " what were supposed to be the smallest of living creatures (*animalium minimum*)," found in wax.

In a somewhat different category, however, are KIRCHER's references to the " verminous blood of fever patients " and to the multitude of minute animals with so many motions, colors, and almost invisible parts. Both have received much consideration from commentators. The first suggests a novel application of the microscope to the examination of a body fluid in disease. The second has led more than one reader to wonder whether KIRCHER did not actually anticipate the great LEEUWENHOEK in the discovery of the protozoa, perhaps even the bacteria. Both statements appear in somewhat more circumstantial forms in the *Scrutinium*. It will be convenient, therefore, to examine them in the course of our discussion of the *Scrutinium* itself, to which we now turn.

It was twelve years after the publication of *Ars magna lucis et umbrae*, namely, in 1658, that the small quarto volume, now usually known as the *Scrutinium pestis*, appeared at Rome under the far more elaborate title given in the bibliography. During the interval, KIRCHER had published five works, including *Musurgia universalis* (1650) in two folio volumes—the scholarly basis of his reputation as a musician—and two massive folio works on Egyptian hieroglyphics : *Obeliscus Pamphilius* (1650) and *Oedipus Aegyptiacus* (1652-4), in three volumes. The last two books represented a long and devoted interest. From the mystic fascinations of hieroglyphics, however, he was torn for a time by news of a ' most atrocious and unheard of plague ' that had

desolated Naples during the summer of 1656 with an enormous loss of life. The *Scrutinium* was the fruit of this new enthusiasm. KIRCHER had had no formal medical training. But " hereafter," a contemporary physician, SINIBALDIUS, writes in his prefatory testimonial, " we shall marvel how this author otherwise devoid of the art of healing, as far as practice and profession go, should write of difficult and abstruse medical matters so vigorously, intimately, skilfully, methodically and profoundly, that there is every reason for me to assert that no professor of medicine of the older generation has come closer with his pen to a conception of the plague." It is in this sense, perhaps, that GARRISON regarded KIRCHER as a " medical man."

There are two references in the *Scrutinium* to the blood of fever patients. One is in Chapter vii, of Section I : " vinegar, milk, and the blood of those sick with fever are full of worms invisible, however, to the unaided eye." The other is in Chapter iv of Section II : " That the matter is not otherwise than I have said, the putrid blood of those afflicted by fevers has fully convinced me; I have found it, an hour or so after letting, so crowded with worms as to well nigh dumbfound me; and I had even been persuaded forthwith that man both alive and dead swarms with numberless but yet invisible little worms; and that this may be the meaning of the words of Job : I have said to corruption, thou art my father; to the worms, my mother and my sister."

This last declaration, though somewhat more elaborate, adds nothing essential to the brief " *de sanguine febrientium verminoso* " of 1646, when KIRCHER was still depending on his flea glass. In the absence of descriptive detail, one can only guess at what he meant in this case by the term *vermes*, which was applied in his day to many sorts of lower organisms, not necessarily what we would call wormlike in form. Pus cells have been suggested, and *Bacillus pestis*—apparently in the belief that KIRCHER was speaking of the bubonic plague rather than, more inclusively, of all serious febrile epidemic disorders. In a passage that we shall see presently, he asserted that his microscope magnified one thousand fold, or, as we might say, about thirty-three diameters. To have seen bacteria not longer than one sixhundredth of a millimeter and only one third as broad, was out of the

question with such an instrument. He *might* have seen red blood corpuscles.

There is reason to believe, however, that KIRCHER may have been using *millies* in an indefinite sense, as the old Romans used *sexcenties*, meaning a very large number. SCHEINER (1626-30) had spoken of " that wonderful instrument, the microscope, by means of which a fly is magnified into an elephant, and a flea into a camel " (SINGER, 1915, 264); and KIRCHER had reiterated these words twenty years later : " *microscopium illud, quo musca in elephantem, & pulex in camelum amplificatur* " (1646, 833) — manifestly a gross exaggeration.

Had he placed a drop of blood on a glass plate and looked through it at a light with a flea glass magnifying not more than five or six diameters, he might very easily have seen, not worms, but innumerable tiny clumps of red corpuscles. To have seen such discrete bodies emerging from what he may have regarded as a homogeneous liquid, might well have astonished him into jumping to an erroneous conclusion. But *did* he see them? To DOBELL (1932, 367), it seemed not unlikely that " in his vague references to ' worms ' occurring in the blood of sick people he was merely harking back to the speculations of antiquity, for example, to the well known passage where PLINY says ' *nascuntur in sanguine ipso hominis animalia exesura corpus* ' (Hist. Nat., lib. xxvi, cap. xiii; ed. Genevae 1932, p. 488." This is quite possible. The passage (S. 86) begins : " *Item phthiriasi—qua Sulla dictator consumptus est, nascunturque*," etc. PLINY was referring to a disease caused by lice, by which SULLA was said to have been destroyed. Lice were known to KIRCHER. If PLINY asserted the presence of vermin in the blood of the sick, it was as easy for KIRCHER to find them there as it was for the contemporaries of VESALIUS to recognize the authority of GALEN even when the latter was in error. If KIRCHER was the first to employ the microscope in investigating the causes of disease his statements about worm-infested blood do not establish the fact; nor is his reputed skill as a microscopist given objective confirmation.

There is, however, other evidence. The seventh chapter of Section I of the *Scrutinium* is unique in containing what KIRCHER entitled *Experimenta consectaria*, six in number. He wished to

establish, by " uncontrovertible experiments," the truth of his assertion that " all putrid matter swarms with a brood of worms without number which are invisible to the unaided eye; which I myself would not have believed had I not proved it by frequent experiments over many years." On these experiments his reputation as a microscopist and an observer may be said to rest. I do not hesitate, therefore, to quote them, as a whole, with a few unimportant omissions that will be indicated as they occur.

" EXPERIMENT 1. Take a piece of meat, and at night leave it exposed to the lunar moisture until dawn of the following day. Then examine it carefully with the microscope and you will find that all the putridity drawn from the moon (caused by the moon) has been transformed into numberless little worms of different sizes, which in the absence of the microscope you will be unable to detect, no matter how sharp sighted, with the exception of those which have grown to such a size as to become visible. You will have the same experience with cheese, milk, vinegar, and similar substances undergoing putrefaction. However, you must not suppose the microscope to be an ordinary one; but highly wrought by a careful and practised hand; such as mine is which represents objects a thousand times larger than they really are."

" EXPERIMENT 2. If you cut a snake into little pieces, soak them in rain water, expose them for some days to the sun, bury them for a whole day and night in the earth, and then, when they are soft with putridity, examine them with a microscope, you will find the whole decaying mass swarming with such a multitude of little snakes that no one has eyes keen enough to count them..."

" EXPERIMENT 3. That unwashed sage is very harmful to those who gather it is granted by Matheiolus, Fuchsius and many other botanists. Moreover, Mizaldus is authority for the statement that some persons, upon eating it, have fallen dead. These scholars attribute the effects to certain toads which poison the roots with their breath, but I have discovered another reason for it. For while I was examining the structure of this plant more minutely with the microscope, I noticed at last that the outer surface of the leaves, which were very rough, was completely covered with spiders' web, within which very tiny little animals were to be seen, continually in motion, with vesicles like eggs spread over the surface; which, as without doubt the offspring of the tiny animals is something of this sort, are thus capable of doing great harm to man with their poisonous secretion. But they immediately disappeared when the leaf was wiped with the finger or washed with water. Thus I have ascertained the true cause of the injurious character of unwashed sage... All these things, which I have learned through repeated experiments, can be determined by others who care to make the trial."

" EXPERIMENT 4. If you examine with the microscope the dust of any rotten wood, you will see an enormous progeny of little worms, some of which have horns, others resemble winged creatures, and still others are not unlike myriapods. You will note also that they have eyes like black points, with a proboscis... To the unaided vision an animal that is smaller than the acarus appears as a white point, but when seen by the microscope, it is revealed to us as a hairy animal, precisely like a bear."

" EXPERIMENT 5. Take a bowl half full of water and sprinkle over it dust of the ground which will soon seek the bottom. Let it remain exposed for a few days to the summer sun, until the water approaches putrescence; and you will observe on the bottom emerging from the sediment in the water or from the dust which was added, certain vesicles which are severally quickened into exceedingly minute worms that play about marvelously in the water. At last, having reached maturity, they are transformed into a vast number of winged gnats (*Cyniphes*). These taking to the air beset men and animals with annoyance and distress which all endure in summer, especially at night."

" EXPERIMENT 6. Every living thing produces from its own decay some congruous animal and different from all others. This we have proved by actual experiment for species of different herbs, and it is true for grain quickened into winged worms. It is just as certain among animals whether highly organized or simple. A dead and rotting ox is quickened into bees, about which see our *Obeliscum Pamphilium*, under the hieroglyph for ox. Horses living and dead produce wasps and beetles which for food then suck the blood of the animals that gave them life, to their great annoyance. Human beings (as well as some Bruta) generate bedbugs, lice and fleas, which are thus as intimate companions provided by nature to draw off corrupted blood. A dead body, foul with decay, becomes a nursery for worms. Remains of insects, when they rot, produce animals of similar nature."

As evidence for KIRCHER's views, these *experimenta irrefragabilia* leave much to be desired. Nevertheless they help us to determine his status as a microscopist. What were the ' countless little worms of different sizes ' in Experiment 1 that he assured his readers *they* would see if they followed his directions, armed with an adequate microscope? There are no identifying marks. What could he have had in mind? " You will have the same experience," he says, " with cheese, milk, vinegar and similar substances undergoing putrefaction." Cheese mites and vinegar eels were already well known. There is nothing to indicate that he was thinking, either in this or any other connection, of infusoria (some of which he *might* have seen without a lens) or bacteria, as certain generous historians have been happy to believe. Not one of his allusions to minute organisms carries with it the conviction of a serious primary interest in microscopical details as was characteristic of contemporary microscopists, from CESI to HOOKE. KIRCHER appears to have been concerned less with observations than arguments, more with the origin of living creatures from putrefying substances than the creatures themselves. Though his argument demanded the " multitude of little snakes " that he predicted in his second experiment, it did not require their careful identification. At the same time, it may

have defined, unintentionally, his true limits as a microscopist. Experiments 3, 4 and 5 recount no observations of an order beyond the range of any likely amateur armed with the popular flea glass. They added nothing to the knowledge of his time. In Experiment 6, there is nothing to attract the experimenter. One assertion is reminiscent of the passage already quoted from PLINY. "Human beings," says KIRCHER, "generate bedbugs, lice and fleas." Compare this ancient saying with the well authenticated views of KIRCHER's contemporary REDI, whose *Esperienze Intorno alla Generazione degl'Insetti* (1668) he was soon to see.

REDI was a member of *del Cimento*, and had been touched by the influence of GALILEO. Modern in method and containing many carefully controlled experiments and searching observations, his slender volume makes an illuminating contrast to the bookish speculations and uncritical observations of KIRCHER. Three years before it appeared, KIRCHER had published his *Mundus subterraneus*, with a bulky consideration of spontaneous generation in Book XII. In it also was another and almost identical edition of Experiment 2 of the *Scrutinium*. In the intervening seven years, KIRCHER had changed neither his attitudes nor methods. This was made especially evident to REDI, who subjected many of KIRCHER's statements to the same controlled experimental tests that he was accustomed to give his own ideas. The results were distressingly unfavorable to the learned father. His circumstantial directions for experiments—had he actually followed them himself? Had he in fact produced young scorpions from the powdered remains of an adult sprinkled with basil water? Had he actually raised frogs from dry ditch dust placed again in water? Had he seen flies, once they had emerged from their pupa cases, continue to grow as he alleged?

To REDI's criticisms, modern both in spirit and method, frankly sceptical of anything but objective evidence, KIRCHER found occasion to respond in his *Arca Noë* (1675). This is a profusely illustrated and circumstantial account of the building of the ark, with cages for its living cargo and drawings of a unicorn among the quadrupeds, a griffin among the flying creatures and a mermaid among the aquatic forms. It was obviously an offering laid upon the altar of doctrine rather than of science.

Confronted, however, with the practical problem of accommodating representatives of all known organisms within a single floating house of refuge, KIRCHER reaffirmed his belief in the spontaneous generation of a large assortment of animals that did not need the protection of the Ark because they could spring up, on occasion, from dormant and invisible seeds scattered throughout the world in its first days by the Creator's hand. He again brought forward the comminuted snakes of Experiment 2, but without further facts or explanations, preferring to rest his credibility as an observer solely on the statement that his most learned colleagues of the Collegio Romano had been witnesses of his work.

With this we may conclude the present section of our discussion. As a microscopist, Father KIRCHER appears to have been foremost neither in time nor significance. He was preceded by discoveries that he never surpassed, and by methods that he never used or understood. Unwilling to give weight to adverse criticism, he continued to combine a credulity exceptional even in his own day with a carelessness for fact that was conspicuously out of keeping with the spirit and the better practices of the developing scientific world into which he was born.

V

In spite of these handicaps, KIRCHER has emerged from a long obscurity as " undoubtedly the first to state in explicit terms, the doctrine of *contagium animatum* as the cause of infectious disease." What does this statement mean? And what are its implications? KIRCHER expressed many times his belief in the animate nature of infectious disease (*de peste animata*). He had, however, precursors.

It will be convenient to begin with THUCYDIDES, whose classic description of the Athenian plague (History, ii, 47-54) was known to KIRCHER but whose objectiveness and critical restraint as an observer the latter did not emulate. " All speculation as to its origin and its causes," said THUCYDIDES... " I leave to other writers, whether lay or professional." Yet he reported, apparently from observation, that " physicians died themselves most thickly, as they visited the sick most often"; and that " all the birds and

beasts that prey upon human bodies, either abstained from touching them (though there were many lying unburied), or died after tasting them. In proof of this, it was noticed that birds of this kind actually disappeared." KIRCHER (II, iv) quotes this and the corresponding passage from LUCRETIUS (VI, 1215ff) as examples of *contagium intrinsecum*. It is interesting that the physician HIPPOCRATES and his colleagues of Cos maintained an unbroken silence on both the Athenian plague and the phenomena of contagion, while THUCYDIDES, the historian with the eyes of an epidemiologist, was recognizing the infectious nature of disease. Furthermore, THUCYDIDES saw that " those who had recovered from the disease... had now no fear for themselves; for the same man was never attacked twice—never at least fatally." He clearly recognized immunity as well.

More than three centuries later, in the sixth book of *De Rerum Natura*, LUCRETIUS gave poetic form and color to THUCYDIDES' account, prefixing, however, a speculative interpretation that the discreet historian had expressly avoided. An ardent disciple of EPICURUS, LUCRETIUS (vi, 1093ff) wrote (as KIRCHER was well aware) : " there are many seeds (*semina*) of things which support life, and on the other hand there must be many flying about which make for disease and death. When these by chance or accident have gathered together, and thrown the heavens into turmoil, the air becomes diseased. And all these diseases in their power and pestilence either come from without down through the sky like clouds and mists, or often they gather together and rise from the earth itself, when through damp it has become putrescent, being smitten out of the time by rains and suns... Accordingly this new plague or pestilence either falls on the waters suddenly, or settles on the corn itself, or other food of mankind or fodder of beasts, or even remains as a force suspended in the air itself; and when breathing we inhale the air mixed with it, this also we must likewise absorb into our body."

The *semina* of EPICURUS and LUCRETIUS were sometimes single atoms, but for the most part, as CYRIL BAILEY (1928, 342) remarks, they were complexes of atoms " of such shape and placed in such arrangements that they are now ready to create particular living or inorganic things." For Atomists like LUCRETIUS, there

was no philosophical barrier between the living and the non-living world, no theoretical need for a fundamental distinction which was, in fact, ignored. This it will be profitable to recall in appraising the views of a much later day.

LUCRETIUS appears never to have referred in so many words to the *semina* of disease as living. His contemporary, MARCUS TERENTIUS VARRO, did so, however, with unmistakable clearness in his *Rerum Rusticarum* (I, 12). It was, however, a passing reference, without elaboration, as to a familiar belief. In giving directions for the location of the farm house, he said: "Precautions must also be taken in the neighborhood of swamps,... because there are bred certain minute creatures (*animalia quaedam minuta*) which cannot be seen by the eyes, which float in the air and enter the body through the mouth and nose and there cause serious diseases." These invisible causes of diseases are not to be confused with mosquitoes, to which, a few lines later, the word *bestiolae* apparently refers. Malaria and mosquitoes were both marsh products in his day, and though not associated pathologically as in ours, both were obnoxious.

VARRO mentions DEMOCRITUS in a long list of authors in the early pages of his book; but neither EPICURUS nor LUCRETIUS is among them. It is in the highest degree unlikely, however, that he, QUINTILIAN'S "*vir Romanorum eruditissimus*," who wrote biographical sketches, with eulogies in verse, of several hundred famous Greeks and Romans (HOOPER and ASH, xvi), had not read the poem of his great contemporary. And it would facilitate a comfortable explanation of the fact that in his *animalia quaedam minuta*, incidentally and familiarly introduced, the *semina morbi* of LUCRETIUS reappear, now explicitly alive.

Fifty years after VARRO died, PLINY (23-79) was born. We have already noted his assertion that ectoparasitic lice arise in the blood of the human bodies that they destroy. Tiny vermin that could yet be seen without the aid of the microscope were thus, with the aid of the imagination, minimized still more and transferred to the blood stream as living agents of disease. As has already been indicated, there is little to choose between PLINY and KIRCHER in this connection.

Let us now pass without pause over the next three centuries to words bearing on the doctrine of the seeds that a good

churchman like Father KIRCHER might well have known. " Nor, in truth, are those evil angels to be called creators," said AUGUSTINE (*De Trinitate*, iii, 8), " because by their means the magicians, withstanding the servant of God, made frogs and serpents. But, in truth, some hidden seeds (*semina*) of all things that are born corporeally and visibly are concealed in the corporeal elements of this world... For, consider, the very least shoot is a seed; for if fitly consigned to the earth, it produces a tree. But of this shoot there is a yet more subtle seed in some grain of the same species, and this is visible even to us. But of this grain also there is further still a seed, which, although we are unable to see it with our eyes, yet we can conjecture its existence from our reason; because, except there were some such power in those elements, there would not so frequently be produced from the earth things which had not been sown there; nor yet so many animals, without any commixture of male and female; whether on the land or in the water, which yet grew, and by commingling bring forth others, while themselves sprang up without any union of parents." AUGUSTINE thus becomes a likely source of KIRCHER's conception of the mechanism of spontaneous generation noted briefly above. And this, as we shall see, was a part of KIRCHER's conception of infectious disease.

It was a belief widely current in the ancient world, that rotting bodies transformed into worms. HOMER, (Iliad, xix, 23), it is true, thought otherwise. ACHILLES, arraying himself for battle after the death of PATROCLUS, feared lest " flies enter the wounds that the bronze hath dealt on the corpse of the valiant son of MENOETIUS, and breed worms therein, and work shame on his corpse—for the life is slain out of him—and so all his flesh shall rot." But this sound and simple recognition of fact awaited experimental confirmation for twenty-four hundred years. Even ARISTOTLE (*Gen. An.*, 762), as KIRCHER knew, shared the common belief in admitting that putrefaction was a possible—though not necessary—condition of the origin of living from lifeless materials. In his opinion, however, spontaneously generated creatures did not burst out of their matrix " perfect forms, limbed and full grown," like the beasts of MILTON (P. L., VII, 455) and the frogs and serpents to which AUGUSTINE naively alludes. He conceived a transformation of the inorganic substrate, activated by a formative

principle, into small and simple, embryonic—perhaps worm-like—forms (*scolices*), which in course of time grew up. He even considered the possible emergence from the earth of autochthonous man as a *scolex*. PLINY (xi, 37-41), though silent on details of their origin, derived insects from filth and lifeless flesh and sour milk; from dust and cloth and paper; from fig trees, pears, pines, and the wild rose; from dew and rain and snow; and from wax, home of the smallest of living creatures (*animalium minimum*). KIRCHER, who specifically referred to these views, accepted them not only without question but added elaborations of his own, applying to them all the doctrine of the seeds which neither ARISTOTLE nor PLINY had mentioned.

Still more common than the association of putrefaction with spontaneous generation was its association with death and disease. From the earliest times, decaying carrion, purulent abscesses, suppurating wounds were common human experiences. ACHILLES mourned that the body of PATROCLUS, slain, would rot. HIPPOCRATES (*Epid.* iii, 4) even saw the gangrenous sick rot before they died. LUCRETIUS (vi, 1100ff) believed that diseases "rise from the earth itself, when through damp it has become putrescent." The relation of putrefaction to disease had long been imbedded in medical lore when FRACASTORO (1646, ix) inquired whether every contagion might be some sort of putrefaction.

It was sixteen centuries after *De Rerum Natura* and more than a century before the *Scrutinium pestis* that GIROLAMO FRACASTORO (1484-1553) published *De Contagione et Contagiosis Morbis et Eorum Curatione, Libri iii.* One is easily tempted to linger over the career of this unusual man. The illuminating account of his life and scientific position by CHARLES and DOROTHEA SINGER (1917), and WRIGHT's translation and introductory essay however, are so accessible that I shall pause only long enough to mention a fact or two of especial interest in the present discussion. He was a physician—as KIRCHER was not—with the best training that Padua could afford, supplemented by a broad clinical experience. PIETRO POMPONAZZI taught him the significance of natural law. COPERNICUS (whose *De Revolutionibus* appeared only three years before *De Contagione*) was a fellow student. NAVIGERO, classical scholar and later editor of LUCRETIUS, was an intimate friend. FRACASTORO in course of time added to

LUCRETIUS' *semina* the ability to propagate bodies similar both in nature and in combination (*mistione*) to themselves; but he maintained a Lucretian indifference to their classification in terms of life. He was an epidemiologist. It was natural for him to connect contagion as he had learned it from the past and observed it in the present with the imperceptible particles (*particulis insensibilibus*) which he later called *seminaria*. It was to be expected that he would adopt the distinction—not original with him—between contagion by direct contact, by contact through intermediary objects to which infective particles might adhere, and by infection through the air. He recognized specificity in disease, and first discriminated typhus fever. He not only observed immunity but wondered whether it might not be possible for man to immunize himself against various diseases.

He related contagion to putrefaction, as had long been done. When, however, he saw that as wine turns to vinegar, " it seems to suffer a sort of contagion by something else but not to suffer putrefaction," he looked far into the future toward the wine casks that made PASTEUR a biologist. It was only incidental to his search for the *causes* of certain fermentative processes that PASTEUR found them in *living organisms*. Nothing brings into stronger relief the essentially modern character of FRACASTORO's imagination than his interest in a mechanism that would interpret observed facts rather than in facts that would merely illustrate doctrine. His observations indicated certain characteristics of the invisible agency of contagion without compelling speculations as to its ultimate nature. With him as with LUCRETIUS, there was no presumptive barrier between inorganic nature and the living world. The origin of disease in the patient himself was assumed in cases where evidence for contagion was entirely lacking. We do the same today. But imperceptible particles that would not only transmit disease but reproduce themselves indefinitely as well were also forced on him by the facts, and he said so. It is a monument to his discretion that he did not say more. Without the aid of the microscope, he foresaw the discoveries of LEEUWENHOEK and their relation to the phenomena of fermentation and disease; he glimpsed a future immunology; and he left an open road to the investigation of the pathogenic viruses unobstructed by vitalistic doctrine.

It is noteworthy that the name of this remarkable and widely read forerunner of KIRCHER nowhere appears in the *Scrutinium*. There is mention of his contemporary, the botanist MATTHIOLI (1554), who applied FRACASTORO's theory of contagion to rabies; and of GERONIMO MERCURIALI (1577), who closely followed the latter's views (SINGER, 1917). KIRCHER quotes a passage from MERCURIALE concerning flies as disseminators of disease which KELLY (1906, ch. 5) reproduces. By an odd oversight in the translation, KELLY attributes this significant statement not to its author, but to KIRCHER, with the flattering comment that the latter " went farther, perhaps, than anyone toward a clear understanding of the part played by insects as carriers of disease." WALSH (1912, 238) echoes the same passage as one evidence of " Father KIRCHER's anticipation of modern ideas with regard to the conveyance of disease." And ROBINSON (1931, 310), accepts it as a " Kircherian observation." It is one way in which reputations are built up.

GERONIMO CARDANO, another contemporary of FRACASTORO, is reported in the *Scrutinium* (I, viii) to have said " that in his own times a most violent pestilence in Milan was caused by an infinity of little worms; whether begotten in dust or in the effluvia of the contaminated air he does not say." Again : " CARDANO relates that one day, according to an ancient story, three soldiers, searching for treasure in Babylon, opened a certain chest, whereupon there suddenly poured forth such a multitude of worms and so intolerable a stench that they were immediately seized by the plague, which infected the entire army and indeed the whole of Asia, with infinite loss of human life " (*De Venenis*). The *vermes* and *vermiculi* of CARDANO bear so strong a resemblance to those of KIRCHER as to suggest a direct line of descent. FRACASTORO, contemplating subtler causes of disease, did not refer to them. But MOUFFET connected the itch mite with scabies as early as 1589; and his observations were published in 1634, the year KIRCHER came to Rome. The latter (1658, I, viii) cites " the celebrated Saxon physician AUGUST HAUPTMANN's little book *de viva mortis imagine* " (1650), in which various minute animal parasites were held to be the causes not only of scabies but of measles and small pox as well (WOODWARD, 1879, 369).

Did KIRCHER make significant additions to this history?

VI

The question brings us back to the *Scrutinium*. First published in 1658, at Rome, it was soon reprinted. The fat little volume in my hands, a copy of the Leipzig edition of 1659, has a preface by CHRISTIAN LANGE, Professor of Medicine at Leipzig, a warm admirer of KIRCHER and translator of the German edition of 1680. From its title page, done into English, comes the following: "By ATHANASIUS KIRCHER, of the Society of Jesus. A physico-medical examination of the contagious pestilence called the plague; in which are brought to light, through a new teaching, the origin, causes, symptoms and signs of the plague, together with suitable remedies, as well as unusual events of a malign nature, which, through the strength and power of celestial influences are manifested at regular intervals, now in the elements, now in the epidemic diseases of men and animals."

The book has three sections. The first considers the origin, causes and effects of the plague; the second, various questions regarding its character and course; the third, curative and prophylactic measures. Only the first now concerns us. " Here, kind reader," says KIRCHER at the end of Chapter viii, " you have my opinion as to the causes of certain obscure diseases; puzzling, perhaps, at first sight, but not out of harmony with the facts to those who have weighed in the calm balance of reason what we have said in the preceding pages about the living nature of the plague (*de peste animata*)." Such a suggestion by the author leaves the critic no choice—except to be brief.

Chapter one presents the plague as a divine punishment for sin. After the deluge, God chastened his erring creatures with war, famine and pestilence. But though originating with God, plagues had their natural causes and their antidotes. Reflecting often on how so much misery might be caused, contagion avoided and the confused wrangling of physicians settled, KIRCHER thought it could be done opportunely by his little work. Whether he had succeeded it would be for the learned and impartial reader to decide.

The plague is defined in Chapter ii as " a disease commonly infesting several regions simultaneously, the cause and origin of dire misfortunes, extremely fatal and contagious "; spreading, as

had long been held, by direct contact and by fomites. It arises (Chapter iii) from the putrid vapors of stagnant marshes that, under the extrinsic heat of the sun, inevitably engender *seminaria* of pestilential disease; from the exhalations of neglected corpses of men slain in battle; from the putrefying bodies of beasts in the fields, of fishes along the shore, of windrows of dead locusts, and flax rotting in the ditches. It arises also from vapors generated by massive putrefactions in the depths of the sea, that find their way to the surface through a labyrinth of subterranean passages, poisoning the air of lethal caves and the earth itself; and " roots absorb these poisons, plants, grass, trees laden with fruits whose mucor exuding from flowers and fruits is quickened into worms and insects of every kind; these both beasts and man receive in food filled with corruption; whence the corruption of the blood by plague-bearing contagion necessarily ensues."

Contagion (Chapter iv) is a certain putrefaction that can originate within the body, as a result of " visceral obstruction and a bad condition of the humors," or externally from air " contaminated with pestiferous effluvia escaping from hidden terrestrial reservoirs of eternal night or the dark mists of celestial influences "; or in both ways. When such polluted air is inspired, the Archaeus of the vital spirits, namely the heart, is attacked and hostile *seminaria* are established; whence contagious putrefaction, " sticky, viscous, profuse and foul," becomes " the inevitable messenger of disease in the living and the fecund propagatrix of the same fatal progeny in the dead."

" All substances in nature " (Chapter vii) " exhale certain effluvia composed " of extremely minute invisible corpuscles... of the same intrinsic nature." Dissipated by heat and returning to the parent body in the cold, they may, if lost, be replaced by particles of the air that " within the secret recesses of the pores are transformed into the natural progeny of the composite," which is thus maintained undiminished. Just as fragrant effluvia refresh and quicken the spirits, so fetid effluvia from a putrefying body oppress them. " Let us now explain how contagion is gradually propagated through disregard of the filth of such putridity."

" Now I assume that somewhere in the world the above-mentioned evaporations from the earth always flourish, surcharged

with evil. It is probable that the first man to imbibe them was especially susceptible, fitted rather to receive poison than to exclude the seeds (*semina*) of a pestilence of this sort; for the propagation of the contagion must begin from one person or from several at the same time... For as the putrid exhalations rise, the air drawn into the lungs is presently expelled in a corrupted condition; ... and when bystanders, or those who care for the sick, breathe this air, they contract the same disease."... " Obviously, this foul and virulent putridity... is the only genuine cause of contagion, since it brings it about that a patient while still alive, emits, together with the vital emanation exhaled into the air, the corpuscles mentioned above which, as I have said, are extremely minute particles of the vital emanation itself, now corrupted."...

" But it is particularly in corpses that the force of such contagion is manifest. For... the power of the creeping putrefaction spreads to all the organs of the body, internal and external; and thus invaded, the corpse dissolves completely into corruption. And under this corruption lurk the true seeds (*semina*) of the plague, which... continually emit the aforesaid corpuscular effluvia on all sides and soon produce a contagion the more dangerous because these corpuscles are endowed with greater vigor and efficiency.

" Corpuscles of this kind are commonly without life (*vita carent*), but through the agency of the circumambient heat already tainted with a similar pollution, they are transformed (*excluduntur*) into a brood of countless invisible little worms; and it is certain that as many worms arise as there are corpuscles in the effluvium. So that the effluvia may now be called, not lifeless, but animate (*animata*)."

" It should be noted that nothing living can originate from decay (*ex putredo formaliter nullum vivens nasci posse*). But when a composite body (*mistum*) which has putrefied is resolved into its elements by the separation of the impure parts from the pure, and when the latter, native to the compound and previously mixed with the putrid, are agitated by heat, then, since nature always intends what is best, it comes to pass that the external heat... transforms the purer parts into something animate (*animatum*). And this is the sole explanation of the origin of living creatures (*viventium*) from putrid matter."...

Again, " no living thing (*nullum animatum*) can be produced from a lifeless body, but only from the seeds of vegetative and sentient nature that are scattered everywhere among the elemental bodies and, after mixing with the moisture of earth or air, are transformed by the energy of the external heat into living animals (*animal vivens*)."

These speculations are now supported by the six *experimenta irrefragabilia* already sufficiently discussed. The chapter ends with the positive declaration that "all putridity contains within itself *seminaria* for the generation of animals, which soon... break out in a discharge of worms that is the more destructive as the putrescence itself... is the more virulent."

The title of Chapter viii announces " That the putridity of corpses infected with the plague is the cause of contagion through the flow of corpuscles both animate and inanimate." After a redundant opening paragraph, the author proceeds : " That the *effluvia animata* are composed of invisible living corpuscles is evident from the multitude of worms that are wont to swarm out of the same bodies. Some grow large enough to be seen; others remain invisible. In number they equal the corpuscles, or particles, composing the effluvium—which indeed are beyond number. Since they are exceedingly subtle, tenuous and light, they are agitated, like atoms (*atomi*) by the least breath of air; but since they have a certain viscosity and glutinous tenacity, they insinuate themselves very easily into the inmost fibers of clothing, cords and linen stuffs; in fact, by virtue of their subtlety, they penetrate any porous material, such as wood, bone, cork, nay, even metals; and there they bring forth new *seminaria* of contagion; and inasmuch as their substance is extremely tenuous, they live for a very long time merely on the moisture which comes to them from without."

VII

In this outline of KIRCHER's views, one recognizes easily the influence of THUCYDIDES, the corpuscular effluvia and *semina morbi* of LUCRETIUS (*animalia minuta* of VARRO), the spontaneous generation of ARISTOTLE, the *semina occulta* of AUGUSTINE, PLINY's *animalia* arising in the blood of the lice-infested sick, CARDANO's

pestiferous *vermes*, HAUPTMANN'S *vermiculi corrodentes*. The *effluvia animata* of KIRCHER embody no new conception and rest explicitly on an age-old error. REDI soon pointed the way toward the truth by means of carefully controlled experiments. But the fact that KIRCHER expressly refused to acknowledge this service suggests that, notwithstanding his microscope, he was still living in the world of AUGUSTINE. The microscope, indeed, became, in his hands, less a tool of research than a brand new garnish for ancient modes of thought.

Such considerations may account for the fact that the *Scrutinium*, after a brief popularity achieved largely through the active promotion of KIRCHER'S admirer, CHRISTIAN LANGE, rapidly lost its initial prestige. KIRCHER himself does not mention it in his autobiography. WALSH (1913, 133) has referred its failure " to produce a greater impression upon the medical research work and teaching of the day and lead to an earlier development of microbiology " to the lack of " instruments of precision necessary to such a study." There can be no doubt that the very slow improvement of the microscope during the next hundred years delayed the development of microbiology in spite of LEEUWENHOEK'S discovery of bacteria and the pioneer observations which he and HOOKE made upon various protista. KIRCHER, however, took no part in these discoveries. He contributed no well authenticated observation to microbiology or the history of infectious disease. He established no useful generalization. He made no stimulating suggestions for research. In his own times, he belonged to the past. And in so far as he failed to affect the future, this, rather than any lack of optic apparatus, would appear to have been the determining factor in the result.

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